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A ZigBee-based Automatic Meter Reading System

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1 Introduction

Automatic Meter Reading (AMR) systems are experiencing a significant growth, hence both consumers and service providers are widely benefiting from this technology. An AMR system can remotely read consumption and other relevant information from meters and automatically record the values in a database. As wireless networking technology also continues to improve in many aspects, AMR systems using wireless technology result in huge savings in the average cost of reading a meter.

ZigBee is a fairly recent wireless sensor network standard that emerges as the low cost wireless networking solution for both industrial and consumer applications. ZigBee offers low power consumption that allows unattended operation for several years, mesh networking ability, secure communication through hostile RF environments, and a sound MAC layer based on IEEE 802.15.4.

In this work, which evolved from a master thesis, we present an AMR system that we designed using ZigBee technology and intended for the Turkish market. We have also developed a simulator that allows us to simulate different topologies and get insights on the performance of the system before implementing it.

2 Aims

In this study, we designed a wireless AMR system that reads the values of water meters in the buildings and transmits the data to a control center. Such a system improves the accuracy of meter reading and billing, while making the whole process much easier. Besides, the costs will be decreased as the need for manpower for manual meter reading is eliminated.

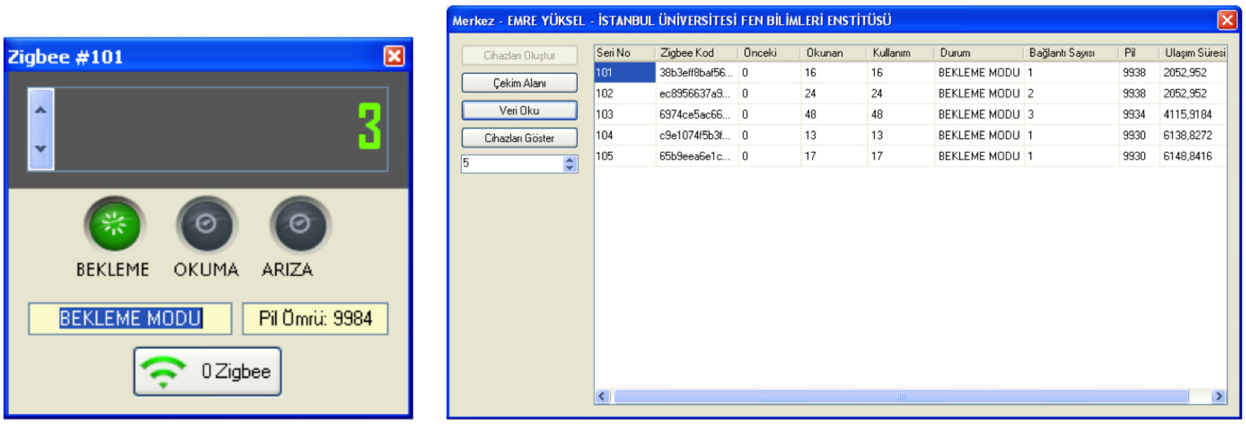
The main benefits of the simulated system can be listed as:

- Several properties of every single ZigBee device such as location and signal strength can be simulated.
- Reachability of devices in cases of device faults can be simulated.
- Battery usage of ZigBee devices can be measured from central control unit, and precautions can be taken before a battery drains.

3 Method

In this section, we skip the details on the system design and present the details on the simulation instead. In order to see how system works and obstruct possible system errors, simulation is very beneficial for every topology.

We have developed a simulator that allows us to simulate different topologies and find out the performance of the system, in `C#`. The screenshots of the interface can be seen in Fig. 1.

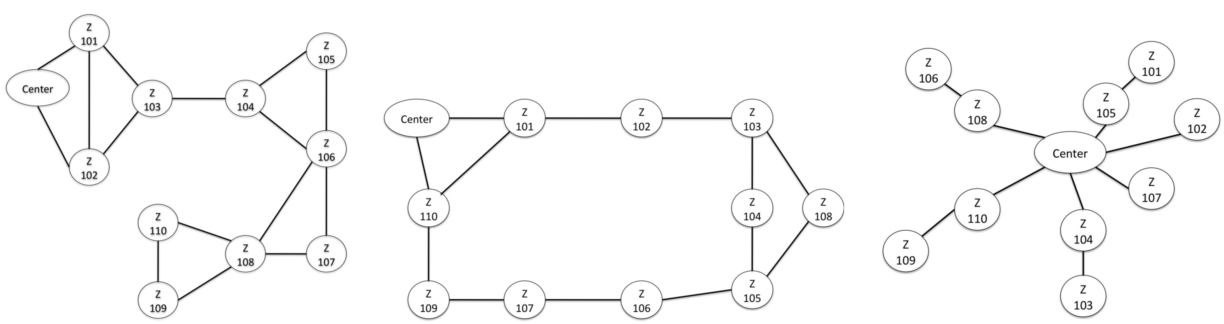


a) A digital meter

b) Control center

Figure 1: Screenshots of the interface.

We have constructed three different topologies for demonstrating how the simulation works. Every single topology in Fig. 2 consists of ten `ZigBee` devices which are all connected to single control center. These topologies can be interpreted as buildings in a little town or street.



a) Topology 1

b) Topology 2

b) Topology 3

Figure 2: Topologies used for simulations.

Next step is defining the analyses that we will be working on using the simulator. We will present the results for two analyses that we define as:

Average Battery Life: In this analysis, the remaining battery life is calculated via simulator for a constant moment. And for the rest of devices in the network, this calculation is being used. This value provides important data about network architecture success and battery life.

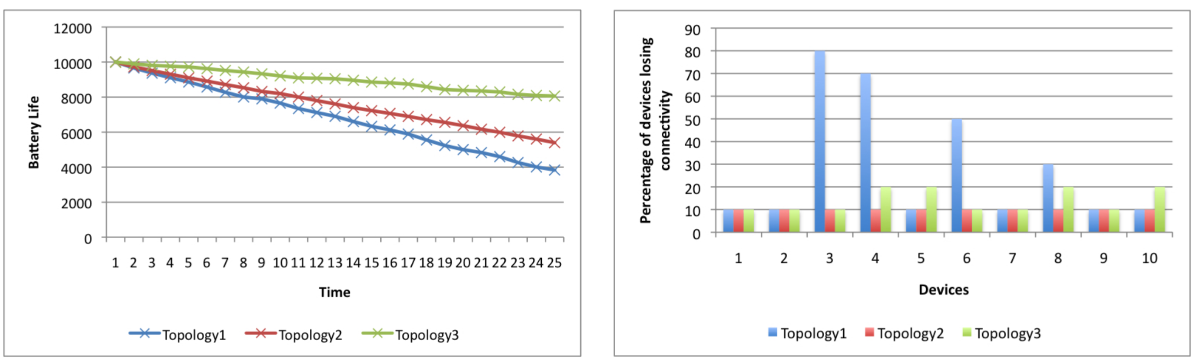
Loss of Connectivity: In this analysis, we investigate the connectivity between each device and the control center. Due to various reasons such as battery drain or device fault, a device can stop functioning and in this analysis we find out how much of the network will be negatively affected from such situations.

4 Results

In this section, we present the results of the simulation on average battery life and loss connectivity analyses.

Average Battery Life: The result of this analysis is shown in Fig. 3.a. Since routing of the packets require more devices in Topology 1, more energy is consumed for data transmission. As an example for the difference between topologies, the farthermost device in Topology 2 connects to the control center via 4 hops, whereas in Topology 1 this requires 6 hops. The best results come from Topology 3 where most of the devices are in the control center's signal field and do not need any hops in order to transmit data.

Loss of Connectivity: The result of this analysis is shown in Fig. 3.b, where we present how a fault in the network affects the connection between control center and other devices, in percentage. The best results came from Topology 2, where a device fault does not affect any other device. In Topology 2, a device fault in either of the devices 4, 5, 8, or 10 will cause 20% of the network stop functioning. The worst results come from the first topology, where 80% of network is affected by a broken device in the worst case.



a) Average battery life

b) Loss of connectivity

Figure 3: Results from simulations.

5 Conclusion

In this work, we designed an AMR system for reading water meters and employed ZigBee wireless sensors for the communication. We developed a simulator to investigate the performance of different topologies, such that before actually implementing such a system to a town we could foresee the possible problems and improve the system. The AMR system and the simulator that we developed are also applicable to other meter readings such as gas or electricity.